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Multiplication Automaticity for Students with Learning Disabilities

Sandra G. Barton

Thesis Submitted in Partial Fulfillment of the Requirements for the  
Degree of Master of Arts in Education

California State University, Monterey Bay

May 2018

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# MULTIPLICATION AUTOMATICITY FOR STUDENTS WITH LD

Multiplication Automaticity for Students with Learning Disabilities

Sandra G. Barton

APPROVED BY THE GRADUATE ADVISORY COMMITTEE

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### **Abstract**

Students with learning disabilities (LDs) often struggle to learn and maintain multiplication automaticity. This research looked at using the computer-based instruction (CBI) program, XtraMath, as an intervention to increase multiplication automaticity for students with LDs. Five fifth-grade students who have math goals stated in their Individual Education Plans (IEPs) were participants in this study. A multiple-baseline-across-participants single-case AB design was conducted to determine the impact XtraMath had on automaticity of multiplication facts (0-9) shown by digits correct per minute (DC/M). Each participant entered the intervention phase (i.e., phase B) separately and provided hard data by completing a two-minute, pencil and paper multiplication probe to show if there was any growth. Data revealed each participant increased their mean DC/M from their mean DC/M in baseline. However, the intervention was effective for only two of the five participants as shown by their non-overlapping data percentages.

*Keywords:* mathematics, multiplication automaticity, learning disabilities, intervention, computer-based instruction

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## Multiplication Automaticity for Students with Learning Disabilities

### **Literature Review**

Finding a comprehensive and agreed upon definition of a learning disability (LD) can be difficult. However, there are common elements in most definitions which include the following characteristics: difficulty acquiring, organizing, or expressing information; visual, auditory, and motor processing problems; memory deficits; and weak abstract-reasoning skills (Steele & Steele, 2003). Students who present with these characteristics often exhibit problems in reading, writing, mathematics, or other school subjects; yet these academic struggles are not caused by intellectual disabilities, behavior disorders, or sensory impairments (Steele & Steele, 2003). If a student is diagnosed with a LD, then an Individualized Education Plan (IEP) is created by a team of people who are responsible for implementing this plan. The IEP ensures all services necessary will be considered, including specialized academic instruction, to aid in the student's success in the general education classroom. By being a holder of this document, the IEP team is legally obligated to set, and work toward goals to attempt to close any achievement gaps the student may be encountering. In order to stay in compliance with the legally mandated IEP, the general education teacher, Education Specialist, and any other providers are responsible to provide accommodations, modifications, and any necessary supports needed to aid in growth, (IDEA, 2004).

The Individuals with Disabilities Education Act (IDEA) mandates that all children with disabilities have an IEP and receive a free and appropriate public education be provided to all eligible children with disabilities (IDEA, 2004). As of 2015, 6.6 million students (13% of all students) in public schools received special education services and 35 percent of the 6.6 million are diagnosed with LDs (NCES, n.d.). Given these percentages and the federal mandates that

require students with disabilities to be educated in the least restrictive environment (LRE), general education teachers will likely have students with LDs in their classrooms (IDEA, 2004). Thus, there is a need for instructional supports to help students with LDs to be successful in the general education classroom.

IDEA (2004) indicated that students with disabilities should be educated with mainstream peers to the extent possible, which for many students with LD, this is often the general education classroom. However, the inclusion of students with LD may pose a challenge for the general education teachers as research indicates that students with LDs often struggle with learning arithmetic facts, including mastering computational fluency, as compared to peers without disabilities (Ok & Bryant, 2015; Woodward, 2006). As a way to ensure that all students, regardless of ability, are educated with similar standards and expectations, the Common Core State Standards (CCSS) were introduced.

In 2010, the CCSS were published as a way for educators to provide consistent learning goals, high-standards, and clear expectations for post-high-school life (National Governors Association Center for Best Practices & Council of Chief State School Officers [NGA/CCSSO], 2010). Furthermore, the CCSS were created to ensure all students receive a similar education and access to a quality education. Educators are required to teach grade level CCSS across the academic domains to all students, regardless of ability level. Yet, there is no clear path to accomplish the mission of reaching the goals of CCSS with various student abilities, including students with LDs. As previously mentioned, Steele and Steele (2003) gave characteristics of LDs as having difficulty acquiring, organizing, or expressing information, which can be especially troublesome when attempting to process and memorize mathematic facts and algorithms required by the CCSS.



The CCSS emphasize on multiplication in mathematics. Multiplication concepts can be difficult for students with LD; yet, the standards must be met for all students regardless of ability level. Therefore, teachers must find ways to instruct *all* students to be successful. Since math concepts are built upon prior knowledge as addressed in the CCSS, it is crucial for students to obtain fundamental multiplication facts to advance in mathematics (Hunt, Valentine, Bryant, Pfannenstiel, & Bryant, 2015; McIntyre, Test, Cooke, & Beattie, 1991; Ok & Bryant, 2015; Skarr et al., 2014; Woodward, 2006). If students fall too far behind in achieving the mathematical standards, they are unable to successfully meet the CCSS and fall further behind their peers. Multiplication is present in the CCSS beginning in second grade and the general progression up to fifth grade is as follows: (1) introduction to multiplication concepts are expected to be taught during the second-grade; (2) interpreting products of whole numbers is a third-grade standard; (3) finding all factor pairs for whole numbers in the range of 1-100 is a fourth-grade standard; and (4) the fifth-grade standard requires students fluently multiply multi-digit whole numbers using the standard algorithm (NGA/CCSSO, 2010). Multiplication fluency or automaticity is required to complete grade level CCSS and to develop more advanced math concepts (Hunt et al., 2015; McIntyre et al., 1991; Ok & Bryant, 2015; Skarr et al., 2014; Woodward, 2006), and so teachers must find ways for all students to be successful; one such way is through the teaching of multiplication automaticity.

### **Multiplication Automaticity**

Being able to quickly answer basic multiplication facts is commonly referred to as multiplication automaticity or multiplication fluency (Burns, 2005; Woodward, 2006). Automatic knowledge of multiplication is a fundamental skill to learn for future math success as higher level math skills are contingent on knowledge of multiplication facts (Hunt et al., 2015;

McIntyre et al., 1991; Ok & Bryant, 2015; Skarr et al., 2014; Woodward, 2006). When multiplication automaticity is not present, students experience a high cognitive load which may lead to additional processing demands and prompt an increased likelihood of erroneous answers (Lewis, 2015; Woodward, 2006). Students with LDs typically make more mistakes and struggle with acquiring multiplication automaticity as compared to typically developing peers (Hunt et al., 2015; Lewis, 2015; Ok & Bryant, 2015). Having the knowledge that attaining multiplication automaticity can be a challenge for students with LDs, and multiplication automaticity is linked to future math success, there is great merit for teachers to provide credible math interventions for students with LDs.

**Interventions as support.** Searching for math interventions for improving multiplication automaticity often referenced strategies for improving reading fluency (Burns, 2005; Lewis, 2010). Demonstrated by the amount of research in the areas of reading and math, it seems that more resources are used to determine the best interventions for reading fluency compared to multiplication fluency or automaticity, where not as much has been done to determine best practices in math interventions for students with LDs (Burns, 2005; Lewis, 2010). There is limited experimental research on strategy instruction in math facts for students with LDs, and the results are mixed in terms of the effective development of automaticity (Woodward, 2006). Students with LDs typically do not develop multiplication automaticity strategies naturally and there is often a need for more intensive interventions (Lewis, 2010; Woodward, 2006).

There is not a one-size-fits-all approach to choosing the most appropriate interventions. Intervention programs and strategies have been researched to guide best practices for teaching multiplication automaticity to students with LDs; yet, teachers often alter the programs and

curriculum to meet the individual needs of their students (Hunt et al., 2015). Hunt and colleagues (2015) reported that special education teachers make adjustments to how the intervention is delivered to students with LDs. Primarily, changes to the intervention are made to reduce the cognitive complexity and to increase students' active involvement with the curriculum. That is, there is a need for programming to be flexible and alterable yet remain effective. Researchers agree that math intervention characteristics should include: direct, explicit, systematic instruction, incremental rehearsal, motivation, increased learning opportunities, and immediate feedback (Hunt et al., 2015; McIntyre et al., 1991; Ok & Bryant, 2015; Skarr et al., 2014; Woodward, 2006).

For students with LDs to develop multiplication automaticity, timed practice drills followed by a systematic review may be used (Woodward, 2006). Furthermore, variations of direct instruction flashcard procedure had shown promising results; it is different than simply using flashcards to assist students with mastering basic facts (Skarr et al., 2014). The intervention, Direct Instruction (DI) flashcard and math racetrack procedures, used the process of systematically practicing multiplication facts with flashcards while using a racetrack game as a motivator to learn the facts quickly (Skarr et al., 2014). The students were given a pre-test to determine which multiplication facts were un-mastered target facts (i.e., the student answered incorrectly). Next, the students were given flash cards with these un-mastered facts and were expected to answer within two seconds. If the student did not know the answer, the instructor would state the answer, and move on to the next question. Students were motivated to respond quickly so they could move their game piece around the race track the fastest. With the implementation of the DI flashcard and math racetrack procedures, there was an immediate increase in the number of facts correct for each set of the students. In addition, the students

generalized from oral to written math instructions without the instruction of written math facts (Skarr et al., 2014). Being able to move from oral to written responses of math facts is essential for future success as most all math classes rely on written responses as the mode of determining if a student understands the presented concepts (e.g., homework, tests). Analyzing paper and pencil multiplication probes is one significant way to measure multiplication automaticity.

The practice of using flashcards in isolation as an intervention, with no written responses, is often unsystematic and its efficacy not evaluated (Skarr et al., 2014). In another study, Leach (2016) incorporated flashcards and direct explicit systematic instruction into an intervention by systematically presenting unknown facts after a series of known facts immediately followed by positive reinforcement (e.g., verbal praise). The results of this research found the intervention to positively impact the participant's motivation and academic success in mathematics. Research shows that interventions providing systematic interventions combined with motivation and repetition prove to be successful methods when teaching multiplication automaticity to students with LDs (Hunt et al., 2015; McIntyre et al., 1991; Ok & Bryant, 2015; Skarr et al., 2014; Woodward, 2006). Systematic interventions in conjunction with explicitly teaching multiplication strategies will benefit all students including those with a LD.

Woodward (2006) focused on comparing two interventions, strategy instruction and timed practice drills. This study used 58 fourth grade students with and without LDs and separated them into two intervention groups, the Integrated group, and the Timed Practice Only group. In the Integrated Group, the students were taught using the number line, arrays, and other visual supports; classroom discussions were encouraged to provide explanations of algorithms used to solve multiplication problems; and 2-minute timed multiplication drills were disbursed through the lessons; automaticity was considered to be 36 correct problems per 2-minutes

(Woodard, 2006). The Time Practice Only group was taught using the direct instruction approach to teach multiplication facts using traditional algorithms as used in a previous study by Stein and colleagues (1997). The direct instruction utilized multiplication worksheets in sequential order, (i.e., multiplying by 1's, then by 2's, then by 3's, etc.), and the problems were delivered systematically easier to harder (Woodward, 2006). Students with and without LD showed positive results using both interventions. However, the Integrated approach proved to have a greater increase in the post-test and maintenance scores compared to the Time Practice Only approach/group (Woodard, 2006). Much of the recent research on multiplication automaticity is based on Woodward's findings (Leach, 2016; Ok & Bryant, 2015), which demonstrates the credibility of the interventions in comparison to other strategies, such as the count-by method.

Another mathematical intervention is the count-by method for multiplication, which is the process of using counting sets of numbers (e.g., 3 times 4 means counting 3 four times; McIntyre et al., 1991). They investigated the effects of using the count-bys method with a fourth-grade student with a LD, and found skill acquisition, maintenance, and generalization of the fluency of single-digit multiplication increased after the intervention (McIntyre et al., 1991). Even though this study did not focus on multiplication automaticity, there was a substantial increase in the correct multiplication facts answered correctly per minute (McIntyre et al., 1991). The Count-By method may be a promising way to teach multiplication facts (McIntyre et al., 1991). Although this method is effective, it is time consuming and is not an appropriate strategy to use in advanced mathematics. Each of the studies reviewed agree on specific elements needed to provide appropriate strategies of a comprehensive math intervention; however, these studies have not accounted for implementation of technology to aid in instruction (Hunt et al., 2015;

McIntyre et al., 1991; Skarr et al., 2014; Woodward, 2006). One such type of technology that could aid in instruction is Computer Based Instruction (CBI) where students use specific programs that focus on their areas of need, such as multiplication automaticity.

**Computer Based Instruction.** CBI uses computer software for instructional purposes and is often recommended for mathematics instruction for students with LDs (Ok & Bryant, 2015). CBI can provide more opportunities to practice timed math fact drills as a method for developing automaticity. This allows the student to work independently, gives immediate feedback, provides adapted individualized instruction, consistently records student's progress, and results indicated significant growth in multiplication fact performance (Ok & Bryant, 2015). Furthermore, McIntyre and colleagues (1991) found that CBI can aid students with LDs to reduce response times to answer multiplication facts and increase their multiplication automaticity. Even though CBI has shown to be effective, finding a specific computer programs or applications that has been used in a peer reviewed study is challenging.

Ok and Bryant (2015) used a strategic intervention using the iPad application, Math Evolve, to perform 1:1 interventions with four students with LDs for multiplication problems with factors of 4 and 8. The factors 4 and 8 were used because these multiplication problems were more difficult than other numbers for the participants (Ok & Bryant, 2015). Four students were tested before the intervention, during the intervention, and two weeks after the intervention. Results showed that the number of digits correct per minute (DC/M) increased with direct intervention using Math Evolve, and this knowledge was maintained after the intervention. This study implemented many of the characteristics of a comprehensive math intervention to aid in the instruction of multiplication automaticity to students with LDs, (Hunt et al., 2015; McIntyre et al., 1991; Ok & Bryant, 2015; Skarr et al., 2014; Woodward, 2006). However, the study was

limited by its small sample size of four students, and assessed for only two digits, 4 and 8, while using the CBI method (Ok & Bryant, 2015). Ok and Bryant's (2015) is the only study that explicitly examined multiplication automaticity among students with LDs using CBI as a support, which shows that additional research on this topic is worth exploring.

**Summary.** Common math interventions available to students with LDs include direct explicit instruction, flashcards, paper and pencil practice, and CBI (Ok & Bryant, 2015; Skarr et al., 2014). Even though numerous researchers have studied math interventions for students with LDs (Hunt et al., 2015; McIntyre et al., 1991; Ok & Bryant, 2015; Skarr et al., 2014; Woodward, 2006), there is a gap in the literature to determine the best practice to teach multiplication automaticity. Furthermore, Woodward (2006) shares that empirical research on strategy instruction in math facts for students with LDs is limited and the results are mixed in terms of the effective development of automaticity. It is difficult to find consensus on effective math interventions to improve multiplication automaticity for students with LDs as many studies have a limited sample size. In addition, teachers frequently vary instruction of specific interventions and curriculum to best suit students and individual circumstances, resulting in questionable fidelity of delivery (Hunt et al., 2015). Delivering curriculum and interventions with fidelity ensures that the method that was researched is the same method that is being delivered. Many of the studies consider one or two of the mentioned elements, but not all combinations of the mentioned elements and strategies have been tried. Further research is warranted to determine appropriate and useful interventions that can be implemented, with fidelity, in the classroom to teach multiplication automaticity to students with LDs. Therefore, the purpose of this research is to examine the impact of a CBI intervention method. The study investigates if there is an increase to the production of correct multiplication facts provided by students with LDs.

Providing a researched based intervention will help teachers and students when selecting alternative and supplemental instruction.

## **Method**

### **Research Question**

Will the CBI program, XtraMath, increase multiplication automaticity in 5<sup>th</sup> grade students with LDs by increasing the number of facts answered correctly in a two-minute time frame?

### **Hypothesis**

Based on prior research (Burns, 2005; Hunt et al., 2015; Leach, 2016; McIntyre et al., 1991; Ok & Bryant, 2015; Skarr et al., 2014; Woodward, 2006), I hypothesized that there would be an increase in the number of multiplication facts that 5th grade students with disabilities could answer correctly after using XtraMath as an intervention.

### **Research Design**

A multiple-baseline-across-participants single-case AB design was conducted to determine the impact XtraMath had on automaticity of multiplication facts (0-9) shown by digits correct per minute (DC/M). Digits correct per minute is defined as each individual digit that is correct. For example, for the math fact  $7 \times 7 = 49$ , 4 (of 49) counts as a correct digit and 9 (of 49) counts as a correct digit. Therefore, the answer of 49 counts as two DC/M. An example is shown on the examiner copy (see Appendix A) and includes the correct answers and the appropriate DC/M per question.

During the study, baseline measurements of students' multiplication automaticity (DC/M) were taken until student performance stabilized, similar to the OK and Bryant (2015) study. All participants entered baseline (i.e. phase A) simultaneously. The baseline was determined when a



student's graphed data plots indicated a near straight line or limited to a visual range. The baseline phase (i.e., phase A) was maintained for a minimum of five data points that were moving in a nontherapeutic direction. Each student's baseline performance acted as his or her own control. Once baseline was established, the first student began the intervention (i.e., phase B) while the other students remained in the baseline condition (i.e. phase A). When the first student demonstrated a therapeutic change in the intervention phase, the second student began intervention (i.e., phase B) while the third student remained in baseline. When the second student demonstrated a therapeutic change in the intervention (i.e. phase B), the third student began joined the previous two students in the intervention phase (i.e., phase B) while the forth student remained in baseline. This process continued with all five participants as seen in Appendix B. There were two phases (A and B) among the five participants.

The intervention consists of using the XtraMath program on the computer. The students worked a minimum of ten minutes practicing multiplication facts on the computer, followed by a two-minute paper and pencil, fifty-question multiplication probe of 0 - 9 facts; this was phase B.

While the participant was practicing the computer instruction intervention, the researcher was sitting nearby to help with any questions or computer glitches that the student could have encountered (e.g., forgot user name or password or clicked somewhere else on the screen and needed to return to the program). Also, the researcher was responsible for monitoring the students and encouraged them to do their best work. If the student took more than 3 seconds to answer a multiplication problem, the program provided the answer. The researcher encouraged the student to take a moment and say the problem and the answer to him or herself a few times before typing in the given answer and moving on. For example, if the student exceeded the time limit answer  $3 \times 7$ , depending on the student's preferred learning style, he or she was encouraged

to speak, sing, tap, write, draw, etc., “ $3 \times 7 = 21$ ,” before typing in the already provided answer of 21. The participant continued working through the XtraMath computer program and when instructed to log off, he or she was given a two-minute multiplication assessment before returning to the general education classroom.

**Independent variable.** The independent variable was the recorded number of sessions. This included baseline and intervention sessions. The intervention was the CBI program, XtraMath (<https://xtramath.org>). The CBI combined with a two-minute curriculum-based measurement (CBM) paper and pencil multiplication probe were used as an example of an explicit, strategic intervention with computer-based practice (Ok & Bryant, 2015).

**Dependent variable.** Multiplication automaticity of facts (0 – 9) demonstrated by the digits correct per minute (DC/M) was the dependent variable. Burns (2005) describes automaticity as the ability to fluently and automatically retrieve multiplication facts (e.g., solve a multiplication problem faster using recall rather than performing an algorithm). The DC/M was calculated after the students were assessed using a CBM: a single-skill multiplication probe generated by the website [www.interventioncentral.com](http://www.interventioncentral.com), in which 50 multiplication problems (factors 0 – 9) was presented.

### **Setting & Participants**

This study took place in a public charter school, serving grades K-8 on the central coast of California. There are 378 students enrolled, and the demographics are as follows: Black or African American, 2%; American Indian, 1%; Asian, 3%; Filipino, 2%; Hispanic or Latino, 21%, White, 57%; Two or more races, 14%. Continuing demographics include: Socioeconomic disadvantaged, 36%; English learners, 3%; Students with disabilities, 11% (School Accountability Report Card, 2016). The five participants were selected utilizing purposeful

convenience sampling based on having a math goal written into their IEPs. None of the students have been retained at any grade level. Participants and classroom teachers were given pseudonyms to protect confidentiality.

Participant 1, Catherine is 12 years and two months, Caucasian, female, LD, and participates in the free/reduced lunch program. She has academic goals in her IEP for mathematics and reading.

Participant 2, Katie is 11 years and two months, Caucasian, female, LD, and does not participate in the free/reduced lunch program. She has academic goals in her IEP for mathematics only.

Participant 3, Daniel is 11 years and five months, Hispanic, male, LD, and participates in the free/reduced lunch program. He has academic goals in his IEP for mathematics and reading.

Participant 4, Karly is 11 years and eight months, Mixed race, female, LD, and does not participate in the free/reduced lunch program. She has academic goals in her IEP for mathematics and writing.

Participant 5, Anne is 11 years and ten months, Caucasian, female, LD, and does not participate in the free/reduced lunch program. She has academic goals in her IEP for mathematics and reading.

Students were included in the general education classroom more than 90% of the time. All participants were on track to receive a high school diploma. The students scored below average or far below average on mathematics standardized testing. There was a total of five participants from two fifth grade classrooms, Ms. Jones's class and Ms. Harper's class which are identified as J and H respectively in Table 1 below.

Table 1

*Participants' Demographic and Testing Information*

Demographic	Catherine	Katie	Daniel	Karly	Anne
Age (years, months)	12.2	11.2	11.5	11.8	11.10
Grade (J/H)	5-J	5-H	5-J	5-H	5-J
Gender	F	F	M	F	F
Race/ethnicity	Caucasian	Caucasian	Hispanic	Mixed race	Caucasian
Disability	LD	LD	LD	LD	LD
Free / reduced lunch	Y	N	Y	N	N
ELL	N	N	N	N	N
IEP Goal areas	Math, Reading	Math	Math, Reading	Math, Writing	Math, Reading
DC/M Baseline					

*Note.* M = Male. F = Female. Y = Yes. N = No. J = Ms. Jones's 5<sup>th</sup> grade student. H= Ms. Harper's 5<sup>th</sup> grade student.

**Measures**

To measure multiplication automaticity, a two-minute CBM paper and pencil multiplication test generated by the website [www.interventioncentral.org](http://www.interventioncentral.org) was administered. Every student was given the same five assessments in the same order. Questions differed for these five assessments to make sure the students did not memorize the answers. The assessments measured the DC/M that the student produced accurately. The five CBM assessments were comprised of 50 multiplication problems (factors 0 – 9; see Appendix A). The two-minute assessments used the same criteria for each student to establish the baseline. This assessment was useful as it determined how many DC/M the student could provide in two minutes at the beginning of the study. Second, during intervention (i.e., phase B), assessments generated by [www.interventioncentral.org](http://www.interventioncentral.org) were administered at least five additional times and were continued until a therapeutic trend is presented.

**Validity.** The paper and pencil measures hold face validity. The website [www.interventioncentral.org](http://www.interventioncentral.org)'s generated CBM probes are found to be a valid form of assessing multiplication facts 0-9 (Lembke & Stecker, 2007).

**Reliability.** The five multiple random assessments administered made the results more reliable by assuring that participants would not receive duplicate assessments consecutively. Each participant was assessed with a different form, yet using the same criteria, during each session. By rotating through five different assessments throughout a six-week timeframe, this made the results more reliable to avoid memorization of assessments to increase scores. Each assessment was reliable because there was a single, correct answer for each item. Another teacher was an observer and surveyed the assessment 20% of the time to ensure the scoring was accurate by double checking the score herself. This procedure was similar to Ok and Bryant (2015) paper which shows that reliable results can be attained by these methods.

### **Intervention**

In this study, the CBI online program XtraMath was used as the intervention. Information regarding XtraMath can be found at [www.xtramath.org](http://www.xtramath.org). XtraMath® is a Seattle 501© (3) nonprofit organization dedicated to math achievement for all ability levels, focusing on increasing speed and accuracy of arithmetic. The focus here was multiplication. The intervention was similar to flashcards, but on the computer, and systematically delivered. There were only a few facts presented during a session, and they were repeatedly administered until the participant achieved the fluency goal, focusing on speed and accuracy (Woodward, 2006). There is man in the video in the corner of the screen who gives encouraging words and explains what to do next.

When the student completed practicing the designated facts, the results were immediately shared. If the answer provided was correct and given within three seconds, the student received a smiley face; correct within ten seconds, a check mark; and if incorrect or longer than ten seconds, a red “X,” and the answer was provided in a light grey color for the student to type over. Once the student typed in the correct answer, the next question was presented. The program makers recommend using XtraMath for ten minutes 3-5 days per week. Within the website, [www.XtraMath.org](http://www.XtraMath.org), once the student’s name was clicked, a progress report displayed mastery in specific facts, along with the section headings: total facts, fluent percentage, right percentage, wrong percentage, timeout percentage, and a quality ranking for the session.

**Fidelity of implementation.** A second observer monitored and signed off to assure the intervention happened the same way across participants (Appendix C). A checklist developed for the fidelity of implementation contained five items that assessed procedural fidelity of implementations using the following scoring system: 0 = not observed, 1 = observed (Appendix D). To calculate the fidelity, the points of behaviors observed by the second observer were divided by the total possible points of all planned behaviors in the checklist and multiplied by 100. The percentages of each student averaged together produced a final percentage to determine the overall fidelity of implementation. The expectation was that there will be a 4/5, or 80% agreement that insured fidelity of this implementation. The observer’s (i.e., reporter’s) scores indicated that fidelity of implementation was at 92%. During the first session observed, the researcher did not read the posted reminder of guidelines which led the reporter to score 4/5 (80%) on the Fidelity Checklist (see Appendix D) for that session for all five participants. During the second, third, and forth sessions observed, the reporter scored 5/5 (100%) implementation for all five participants. During the last session observed, the reporter did not

observe the researcher sitting next to the students during the CBI time, leading to another score of 4/5 (80%) for all five participants. The average of all of the above scores supports the reporter's score of 92% fidelity of implementation.

**Data collection.** Data was collected on each participant after a two-minute multiplication assessment was scored. To calculate the score, the total digits written within the two-minute timeframe was divided by two to calculate how many digits were produced in one minute. Once the DC/M was calculated on each assessment, it was graphed. The XtraMath program provided additional data regarding how frequently the student participated using the program, what the trouble facts were, and what facts were mastered. The CBM probe created by the website [www.interventioncentral.org](http://www.interventioncentral.org) in which 50 multiplication problems (factors 0 – 9) was developed and DC/M was calculated and graphed to visually display trends. Once the trends were established, the intervention remained in practice until the end of the study. Several assessments of the two-minute multiplication probes were double-scored. Twenty percent of the assessment probes were scored independently by the investigator and researcher. There were approximately 30 sessions, and 20% of the 30 sessions required that six sessions be observed (Appendix C).

### **Ethical Considerations**

Ethical considerations for this study include the modalities used when practicing on the computer are different when using a paper and pencil to provide answers. The students may need time to adjust to typing in their answers as the school does not typically employ computers for instruction. The intent was that the repetition of the multiplication facts would transfer and be applied to other areas, environments, and situations for the student's advantage. The fifth-grade students who have math goals in their IEPs are already familiar to attending the resource

room for specialized academic instruction. Participants will not encounter any extra time out of class and will continue to work toward their IEP math goals in a normal fashion.

**Validity threats.** Potential extraneous variables included whether the participant ate breakfast, as the interventions took place as soon as school began. To address this, a basket of fruit was accessible to all students. Another possible bias was the researcher's motivation for them to show growth, by giving extra prompting, time, or certain looks, the researcher might influence the results. To avoid this, the researcher had reminders to avoid the above-mentioned behaviors before each session. If there were gaps in services, due to absences, school activities, field trips, etc., this could have influenced the outcome. If sessions were missed, an effort was made to make up that time.

### **Data Analyses**

Data were graphed for each students' performance by displaying the sessions on the horizontal x-axis, and DC/M shown on the y-axis. This allowed for visual inspection of any trends (e.g., an increase, decrease or steadiness in DC/M). Visual analysis included trends in the data and percentage of non-overlapping data points. The non-overlapping data percentage was calculated by identifying the highest DC/M value during the baseline (phase A), then finding how many times the participant exceeded that value during the intervention (phase B). The calculation is a percentage of how many times the value was exceeded by the total number of opportunities in the intervention phase. Larger percentages indicate that the intervention was more beneficial to the student compared to lower percentages.

**Social validity.** At the completion of the study, the participants and classroom teacher completed a four-point Likert scale (i.e., *1 = strongly disagree to 4 = strongly agree*) social validity questionnaire (see Appendix E). The questionnaire, adapted from Berger, Manston and



Ingersoll (2016), consisted of eight questions designed to understand the perceived usefulness, significance and satisfaction with the implemented intervention (Kennedy, 2005). Participant responses were kept confidential and descriptive statistics were conducted to gain insights regarding the intervention.

The participants in this study were from two different classrooms. The respective classroom teachers completed the questionnaire and similarly agreed: the intervention was acceptable for increasing the student's skills, would suggest the use of this treatment (i.e., intervention) to other individuals, and the treatment (i.e., intervention) decreased the level of stress experienced by the student during math in the class. One of the two teachers agreed this treatment was effective. Both fifth-grade teachers responded identically that they would not be willing to carry out this treatment (i.e., intervention) themselves.

## **Results**

This study investigated the use of the CBI XtraMath intervention for five fifth-grade students with LDs using a multiple-baseline-across-participants single-case AB design and the results are depicted in Figure 1. The session number is represented on the x-axis and the DC/M (i.e., measure) is represented on the y-axis on the graph (see Figure 1). The baseline data of each participants' DC/M (i.e., phase A) is shown to the left of the horizontal dotted line. The horizontal dotted line (i.e., phase change line) represents when the intervention began for each participant. The data points to the right of the of the phase change line indicate the DC/M for each participant while in intervention. The mean, range, and percentage of non-overlapping data for each participant baseline and intervention phases are in Table 2.

Table 2

*Participants' Results*

Results	Catherine	Katie	Daniel	Karly	Anne
Baseline Mean	26.38	17.55	15.97	19.01	16.66
Intervention Mean	34.10	20.83	20.88	29.36	23.33
Baseline Range	24 - 28	11.5 – 21.5	10 – 20	16 – 23	7 - 24
Intervention Range	24 – 41	12 – 24.5	10.5 – 31	19 – 37	21 – 26
Percentage of Non-Overlapping Data	88.46%	33.33%	43.75%	90.91%	33.33%

Catherine (participant 1) had a 29% increase from baseline mean to intervention mean. The highest DC/M during baseline increased by 46% during the intervention. Five data points were collected to determine Catherine's baseline (i.e., phase A;  $M = 26.40$ , range = 24 – 28 DC/M). During the intervention (i.e., phase B) there was a lot of variability, yet the results suggest that the intervention was an increase to the mean and range ( $M = 34.10$ , range 24 – 41 DC/M, with 88% non-overlapping data).

Katie (participant 2) had a 19% increase from baseline mean to intervention mean. The highest DC/M during baseline increased by 14% during the intervention. Katie was second to enter the intervention, therefore was in baseline ( $M = 17.55$ , range = 11.5 – 21.5 DC/M) for a longer period than participant one. Katie's intervention data results indicated there was an increase of DC/M ( $M = 20.83$ , range = 12 – 24.5, with 33% non-overlapping data).

Daniel (participant 3) had a 31% increase from baseline mean to intervention mean. The highest DC/M during baseline increased by 55% during the intervention. Daniel was third to enter the intervention, therefore was in baseline (i.e., phase A) for a longer period than the previous participants ( $M = 15.97$ , range = 10 – 20 DC/M). Daniel's intervention data results indicated there was an increase of DC/M, ( $M = 20.88$ , range = 10.5 - 31, with 44% non-overlapping data).

Karly (participant 4) had a 55% increase from the mean baseline to the mean intervention scores. The highest DC/M during baseline increased by 61% during the intervention. Karly was forth to enter the intervention; therefore, was in baseline (i.e., phase A) for a longer period than the previous participants ( $M = 19.01$ , range = 16 – 23 DC/M). Karly's intervention data results indicated there was a significant increase of DC/M, ( $M = 29.36$ , range = 19 - 37, with 91% non-overlapping data).

Anne (participant 5) had a 40% increase from baseline mean to intervention mean. The highest DC/M during baseline increased by 8% during the intervention. Anne was last to enter the intervention; therefore, was in baseline (i.e., phase A) for the longest period. Her baseline data reflected ( $M = 16.66$ , range = 7 – 24 DC/M). Anne was in phase B for the shortest amount of time compared to the other participants. Her data results indicated there was an increase of DC/M, ( $M = 23.33$ , range = 21 – 26, with 33% non-overlapping data).

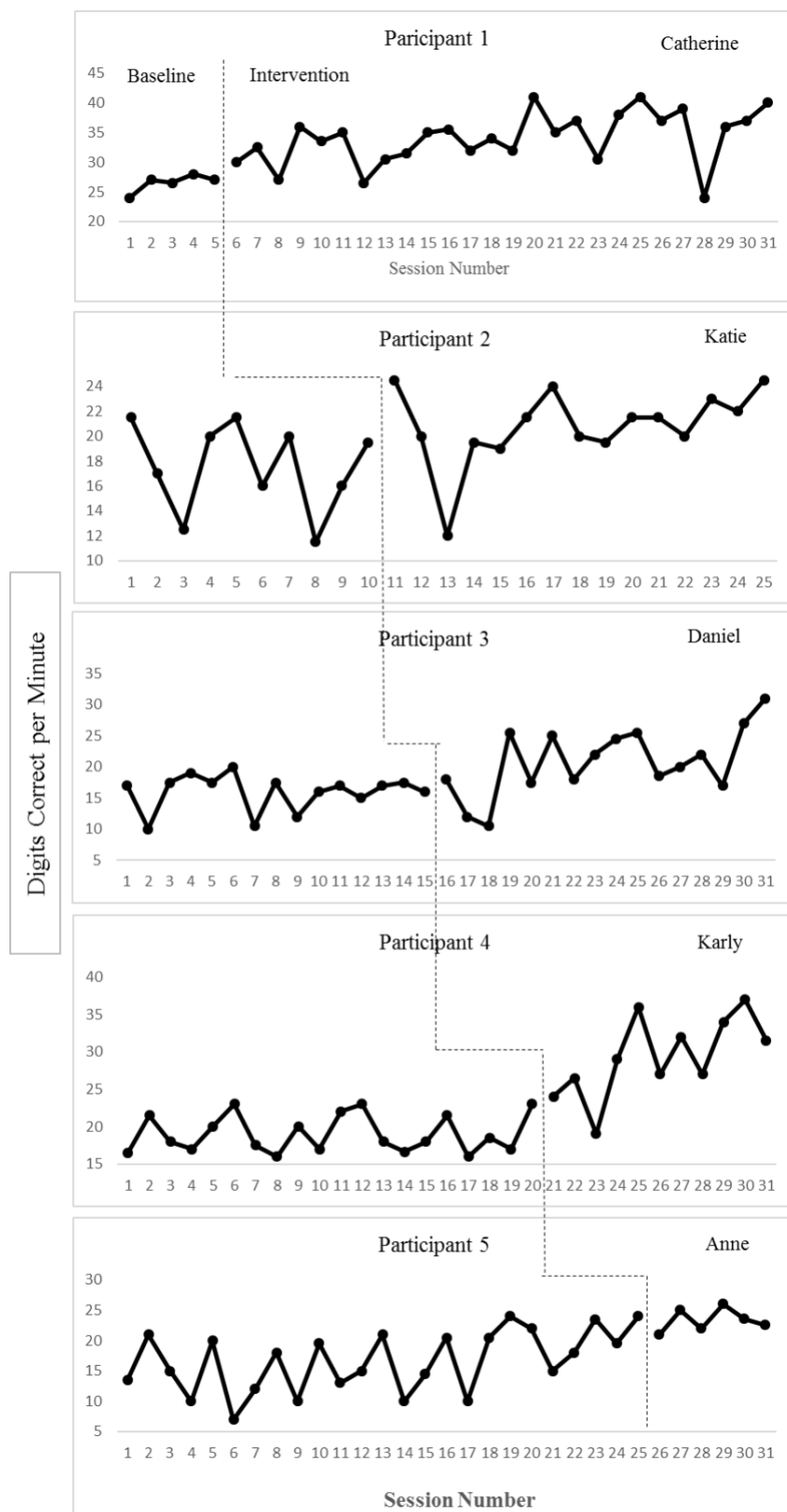


Figure 1. Multi-baseline across participant's single case AB design representing the five participants baseline and intervention phase data.

### **Discussion**

The purpose of this study was to examine the impact of CBI XtraMath with five students in the fifth grade who have LDs. The focus was to see if the overall multiplication automaticity rates would improve. The hypothesis stated that there would be an increase in the number of multiplication facts that 5th grade students with disabilities could answer correctly after using XtraMath as an intervention. Results indicated that there was a clear, functional relationship between XtraMath and an increase in the students' multiplication automaticity for two of the five participants. For these two participants, this intervention was effective as shown by their percentages of non-overlapping data. For Karly (participant 4), the intervention was highly effective as her data were 91% non-overlapping. Catherine (participant 1) had similar results as her data were 89% non-overlapping. Although there was an increase in the mean of the DC/M from baseline to intervention for the remaining three of the five participants, this intervention was deemed to be non-effective as their percentage of non-overlapping data was less than 50%.

The data collected were much more sporadic than anticipated as smooth trend lines did not occur. One possibility for the fluctuation among all participants may be linked to the severity of the student's disability or the combination of disabilities the student experiences. Even though all participants have LD, some have secondary disabilities. The two participants who responded quickly and which the intervention was highly effective, have IEPs for specific learning disabilities (SLD) and speech and language impairment (SLI) with no known history of behavior or attention issues. The following are students for whom the intervention was not effective: Katie (participant 2), Daniel (participant 3), and Anne (participant 5). These three students have multiple challenges that contribute to their learning difficulties (e.g., dyslexia,

ADHD, and behaviors) and this could be a possible explanation of why the response to the intervention varied among the participants.

Research has shown that academic performance is impacted due to various or combinations of processing disorders among students with LDs (Steele & Steele, 2003). Moreover, research indicates that students with LDs experience difficulties mastering multiplication automaticity compared to their peers without LD (e.g., low fact retrieval, commit more errors, and use developmentally immature strategies) (Ok & Bryant, 2015). Research by Ok and Bryant (2015) remind us that students with different disabilities respond differently to interventions. Finding evidence to support this intervention works with students with LD in increasing multiplication automaticity is a challenge since it has proven to be effective for two of the five participants. There is no all-encompassing way to learn a skill, especially increasing multiplication automaticity for students with LD.

Disabilities that qualified the student to have an IEP were not taken into consideration at the beginning of the study; however, they look to be relevant in the results. Additionally, the length of participation in the intervention does not seem to correlate to the usefulness of the intervention. For example, Catherine (participant 1) was in intervention phase for twenty-six sessions, and Karly (participant 4) closely replicated Catherine's results when in the intervention phase for only eleven sessions. Similarly, Katie (participant 2) was in the intervention phase for fifteen sessions and Anne (participant 5) was in the intervention phase for six sessions. Anne's minimal exposure the intervention phase should be considered in the data analysis, as number of sessions correlating to intervention effectiveness may be addressed in future studies.

### **Limitations and Future Direction**

There were two main limitations to this study, using convenience sampling and time. The convenience method was used as these participants were the only participants available to the researcher to perform this study. In the future, it would be more effective to use a larger sample size (e.g., more students and more sessions) to determine how results can vary or maintain. It would be beneficial to see how this intervention works with students with and without learning disabilities, as well as how effective the intervention is with specified learning disabilities. The second limitation was time as this study was conducted in one semester. There were timeline restrictions on how long the student could remain in baseline and intervention phases. Future studies could be implemented throughout an entire school year to provide more accurate data on student performances.

In conclusion, this study contributed to the research on the topic of interventions to teach multiplication automaticity to students with LDs. As shown, this intervention was highly effective for some of the participants which warrants further studies. The intervention in this study was substantiated by the studies previously reviewed, to include direct explicit instruction, flashcards, paper and pencil practice, and CBI (Ok & Bryant, 2015; Skarr et al., 2014). This study sought to add to the literature of evidence-based interventions for increasing multiplication automaticity for students with LD.

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**Appendix A:**  
Curriculum-Based Assessment  
Mathematics Single-Skill Computation  
Probe: Student Copy

Student: \_\_\_\_\_

Date: \_\_\_\_\_

$$\begin{array}{r} 9 \\ \times 3 \\ \hline \end{array}$$

$$\begin{array}{r} 6 \\ \times 7 \\ \hline \end{array}$$

$$\begin{array}{r} 9 \\ \times 6 \\ \hline \end{array}$$

$$\begin{array}{r} 1 \\ \times 6 \\ \hline \end{array}$$

$$\begin{array}{r} 7 \\ \times 6 \\ \hline \end{array}$$

$$\begin{array}{r} 2 \\ \times 2 \\ \hline \end{array}$$

$$\begin{array}{r} 5 \\ \times 2 \\ \hline \end{array}$$

$$\begin{array}{r} 4 \\ \times 9 \\ \hline \end{array}$$

$$\begin{array}{r} 5 \\ \times 8 \\ \hline \end{array}$$

$$\begin{array}{r} 3 \\ \times 4 \\ \hline \end{array}$$

$$\begin{array}{r} 3 \\ \times 2 \\ \hline \end{array}$$

$$\begin{array}{r} 2 \\ \times 1 \\ \hline \end{array}$$

$$\begin{array}{r} 1 \\ \times 7 \\ \hline \end{array}$$

$$\begin{array}{r} 6 \\ \times 3 \\ \hline \end{array}$$

$$\begin{array}{r} 1 \\ \times 2 \\ \hline \end{array}$$

$$\begin{array}{r} 9 \\ \times 2 \\ \hline \end{array}$$

$$\begin{array}{r} 1 \\ \times 5 \\ \hline \end{array}$$

$$\begin{array}{r} 2 \\ \times 7 \\ \hline \end{array}$$

$$\begin{array}{r} 3 \\ \times 4 \\ \hline \end{array}$$

$$\begin{array}{r} 3 \\ \times 1 \\ \hline \end{array}$$

2

1

1

8

x1x6x4x6
$$\begin{array}{r} 7 \\ \times 3 \\ \hline \end{array}$$
$$\begin{array}{r} 6 \\ \times 5 \\ \hline \end{array}$$
$$\begin{array}{r} 7 \\ \times 2 \\ \hline \end{array}$$
$$\begin{array}{r} 1 \\ \times 7 \\ \hline \end{array}$$
$$\begin{array}{r} 6 \\ \times 4 \\ \hline \end{array}$$
$$\begin{array}{r} 1 \\ \times 7 \\ \hline \end{array}$$
$$\begin{array}{r} 7 \\ \times 2 \\ \hline \end{array}$$
$$\begin{array}{r} 3 \\ \times 2 \\ \hline \end{array}$$
$$\begin{array}{r} 5 \\ \times 5 \\ \hline \end{array}$$
$$\begin{array}{r} 2 \\ \times 8 \\ \hline \end{array}$$
$$\begin{array}{r} 5 \\ \times 9 \\ \hline \end{array}$$
$$\begin{array}{r} 2 \\ \times 8 \\ \hline \end{array}$$
$$\begin{array}{r} 3 \\ \times 8 \\ \hline \end{array}$$
$$\begin{array}{r} 1 \\ \times 4 \\ \hline \end{array}$$
$$\begin{array}{r} 3 \\ \times 1 \\ \hline \end{array}$$
$$\begin{array}{r} 3 \\ \times 5 \\ \hline \end{array}$$

Curriculum-Based Assessment Mathematics  
Single-Skill Computation Probe: Examiner Copy

*MULTIPLICATION: Multiplication facts: 0 to 9*

Item 1:  
2 CD/2 CD Total

$$\begin{array}{r} 9 \\ \times 3 \\ \hline 27 \end{array}$$

Item 2:  
2 CD/4 CD Total

$$\begin{array}{r} 6 \\ \times 7 \\ \hline 42 \end{array}$$

Item 3:  
2 CD/6 CD Total

$$\begin{array}{r} 9 \\ \times 6 \\ \hline 54 \end{array}$$

Item 4:  
1 CD/7 CD Total

$$\begin{array}{r} 1 \\ \times 6 \\ \hline 6 \end{array}$$

Item 5:  
2 CD/9 CD Total

$$\begin{array}{r} 7 \\ \times 6 \\ \hline 42 \end{array}$$

Item 6:  
1 CD/10 CD Total

$$\begin{array}{r} 2 \\ \times 2 \\ \hline 4 \end{array}$$

Item 7:  
2 CD/12 CD Total

$$\begin{array}{r} 5 \\ \times 2 \\ \hline 10 \end{array}$$

Item 8:  
2 CD/14 CD Total

$$\begin{array}{r} 4 \\ \times 9 \\ \hline 36 \end{array}$$

Item 9:  
2 CD/16 CD Total

$$\begin{array}{r} 5 \\ \times 8 \\ \hline 40 \end{array}$$

Item 10:  
2 CD/18 CD Total

$$\begin{array}{r} 3 \\ \times 4 \\ \hline 12 \end{array}$$

Item 11:  
1 CD/19 CD Total

$$\begin{array}{r} 3 \\ \times 2 \\ \hline 6 \end{array}$$

Item 12:  
1 CD/20 CD Total

$$\begin{array}{r} 2 \\ \times 1 \\ \hline 2 \end{array}$$

Item 13:  
1 CD/21 CD Total

$$\begin{array}{r} 1 \\ \times 7 \\ \hline 7 \end{array}$$

Item 14:  
2 CD/23 CD Total

$$\begin{array}{r} 6 \\ \times 3 \\ \hline 18 \end{array}$$

Item 15:  
1 CD/24 CD Total

$$\begin{array}{r} 1 \\ \times 2 \\ \hline 2 \end{array}$$

Item 16:  
2 CD/26 CD Total

$$\begin{array}{r} 9 \\ \times 2 \\ \hline 18 \end{array}$$

# MULTIPLICATION AUTOMATICITY FOR STUDENTS WITH LD

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Item 17:  
1 CD/27 CD Total

$$\begin{array}{r} 1 \\ \times 5 \\ \hline 5 \end{array}$$

Item 18:  
2 CD/29 CD Total

$$\begin{array}{r} 2 \\ \times 7 \\ \hline 14 \end{array}$$

Item 19:  
2 CD/31 CD Total

$$\begin{array}{r} 3 \\ \times 4 \\ \hline 12 \end{array}$$

Item 20:  
1 CD/32 CD Total

$$\begin{array}{r} 3 \\ \times 1 \\ \hline 3 \end{array}$$

Item 21:  
1 CD/33 CD Total

$$\begin{array}{r} 2 \\ \times 1 \\ \hline 2 \end{array}$$

Item 22:  
1 CD/34 CD Total

$$\begin{array}{r} 1 \\ \times 6 \\ \hline 6 \end{array}$$

Item 23:  
1 CD/35 CD Total

$$\begin{array}{r} 1 \\ \times 4 \\ \hline 4 \end{array}$$

Item 24:  
2 CD/37 CD Total

$$\begin{array}{r} 8 \\ \times 6 \\ \hline 48 \end{array}$$

Item 25:  
2 CD/39 CD Total

$$\begin{array}{r} 7 \\ \times 3 \\ \hline 21 \end{array}$$

Item 26:  
2 CD/41 CD Total

$$\begin{array}{r} 6 \\ \times 5 \\ \hline 30 \end{array}$$

Item 27:  
2 CD/43 CD Total

$$\begin{array}{r} 7 \\ \times 2 \\ \hline 14 \end{array}$$

Item 28:  
1 CD/44 CD Total

$$\begin{array}{r} 1 \\ \times 7 \\ \hline 7 \end{array}$$

Item 29:  
2 CD/46 CD Total

$$\begin{array}{r} 6 \\ \times 4 \\ \hline 24 \end{array}$$

Item 30:  
1 CD/47 CD Total

$$\begin{array}{r} 1 \\ \times 7 \\ \hline 7 \end{array}$$

Item 31:  
2 CD/49 CD Total

$$\begin{array}{r} 7 \\ \times 2 \\ \hline 14 \end{array}$$

Item 32:  
1 CD/50 CD Total

$$\begin{array}{r} 3 \\ \times 2 \\ \hline 6 \end{array}$$

Item 33:  
2 CD/52 CD Total

$$\begin{array}{r} 5 \\ \times 5 \\ \hline 25 \end{array}$$

Item 34:  
2 CD/54 CD Total

$$\begin{array}{r} 2 \\ \times 8 \\ \hline 16 \end{array}$$

Item 35:  
2 CD/56 CD Total

$$\begin{array}{r} 5 \\ \times 9 \\ \hline 45 \end{array}$$

Item 36:  
2 CD/58 CD Total

$$\begin{array}{r} 2 \\ \times 8 \\ \hline 16 \end{array}$$

Item 37: 2 CD/60 CD Total	Item 38: 1 CD/61 CD Total	Item 39: 1 CD/62 CD Total	Item 40: 2 CD/64 CD Total
3	1	3	3
x 8	x 4	x 1	x 5
<b>24</b>	<b>4</b>	<b>3</b>	<b>15</b>

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# MULTIPLICATION AUTOMATICITY FOR STUDENTS WITH LD

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## Appendix B:

### Multiple Baseline Design - Single Case Study

Phase Explained:	Phase 1: Establish Baseline	Phase 2: Intervention				
<b>Participant 1</b>	X x x x x (or until they level out) for <b>baseline</b> (x represents data points from assessments)	<b>Intervention &amp; Paper and Pencil</b> assessment. Plots are gathered to establish a visual <b>trend</b>				
<b>Participant 2</b>	X x x x x (or until they level out) for <b>baseline</b>	X x x x x (or until they level out) for <b>baseline</b>	<b>Intervention &amp; Paper and Pencil</b> assessment. Plots are gathered to establish a visual <b>trend</b>			
<b>Participant 3</b>	X x x x x (or until they level out) for <b>baseline</b>	X x x x x (or until they level out) for <b>baseline</b>	X x x x x (or until they level out) for <b>baseline</b>	<b>Intervention &amp; Paper and Pencil</b> assessment. Plots are gathered to establish a visual <b>trend</b>		
<b>Participant 4</b>	X x x x x (or until they level out) for <b>baseline</b>	X x x x x (or until they level out) for <b>baseline</b>	X x x x x (or until they level out) for <b>baseline</b>	X x x x x (or until they level out) for <b>baseline</b>	<b>Intervention &amp; Paper and Pencil</b> assessment. Plots are gathered to establish a visual <b>trend</b>	
<b>Participant 5</b>	X x x x x (or until they level out) for <b>baseline</b>	X x x x x (or until they level out) for <b>baseline</b>	X x x x x (or until they level out) for <b>baseline</b>	X x x x x (or until they level out) for <b>baseline</b>	X x x x x (or until they level out) for <b>baseline</b>	<b>Intervention &amp; Paper and Pencil</b> assessment. Plots are gathered to establish a visual <b>trend</b>

Phase 1 Explanation: **Take 5 BASELINE data points until trend is established (at least 5 data-points) using a two-minute paper and pencil assessment (50 questions, 0-9 facts)**

Phase 2 Explanation: **Start XtraMath Intervention followed by a two-minute paper and pencil assessment (50 questions, 0-9 facts)**



**Appendix C:**

## Interobserver Agreement

<b>Date</b>	<b>Day of the Week</b>	<b>Double-Scored (multiplication two- minute probe)</b>	<b>Participant Number</b>	<b>Signature / Initial</b>
2/28/18	Wednesday			
3/6/18	Tuesday			
3/8/18	Thursday			
3/12/18	Monday			
3/14/18	Wednesday			
3/19/18	Monday			

Twenty percent of the 30 sessions held required six sessions needed to be observed.

**Appendix D**

## Fidelity Checklist

Directions: The second observer is to responsible for checking the fidelity of the implementation of the procedures stated in the study. Write the observed score on the line to the left of the statements using the following numbers:

0 = not observed

1 = observed

- \_\_\_\_\_ The researcher will read posted reminder of guidelines (no prompting, hint at answers, provide extra time, etc.)
- \_\_\_\_\_ The 2-minute probe was administered during the baseline phase, and no other elements of the study were presented.
- \_\_\_\_\_ The XtraMath CBI instruction was implemented after the baseline (minimum of 5 data points) was established. No more than 15 minutes was spent on the computer.
- \_\_\_\_\_ During Phase II, after XtraMath instruction, a 2-min multiplication (0-9) probe was administered.
- \_\_\_\_\_ The researcher sat next to the student during the computer instruction time to answer any computer-related questions, and to remind the student to practice before entering the answer (when the answer is provided in grey when the time runs out).

**Appendix E**

## Social Validity Questionnaire

Questions:		1 Strongly disagree	2 Disagree	3 Agree	4 Strongly Agree
1	This treatment of Xtra math was effective				
2	I found this treatment acceptable for increasing the student's skills				
3	Using the treatment improved skills across multiple contexts (home, classroom, community)				
4	I think the student's skills would remain at an improved level even after the treatment ends				
5	This treatment quickly improved the student's skills				
6	I would be willing to carry out this treatment myself if I wanted to increase the student's skills				
7	I would suggest the use of this treatment to other individuals				
8	This treatment decreased the level of stress experienced by the student during math class				